

LIGHT IN MEDICINE

Light has some interesting properties, many of which are used in medicine:

1- The speed of light changes when it goes from one material into another. The ratio of the speed of light in a vacuum to its speed in a given material is called the index of refraction.

2- Light behaves both as a wave and a particle. As a wave it produces interference and diffraction. As a particle it can be absorbed by a single molecule.

3- When light is absorbed, its energy generally appears as heat. This property is the basis for the use IR light to heat tissues. Also the heat produced by laser beams is used to weld a detached retina to the back of eyeball and to coagulate small blood vessels in retina.

4- Some time when a light photon is absorbed, a lower energy light photon is emitted. This property is known as fluorescence.

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5- Light is reflected to some extent from all surfaces. There are two types of reflection

A- Diffuse reflection: occurs when rough surface scatter the light in many direction

B- Specular reflection: it is obtained from very smooth surface such as mirrors.

MEASUREMENT OF LIGHT AND ITS UNITS

- The three general categories of light-UV, Visible, and IR- are defined in terms of their wavelengths. Wavelength of light used to be measured in

Microns **$1 \mu = 10^{-6}m$** •

Angstroms **$1 A^{\circ} = 10^{-10}m$** •

Nanometer **$1 nm = 10^{-9}m$** •

- Ultraviolet light has wavelengths from 100 to 400nm
- Visible light has wavelengths 400 to 700nm
- IR light has wavelengths from 700 to 10^4 nm.

Each of these categories subdivided according to wavelength.

Ultraviolet **UV-A** has wave lengths from 320 – 400nm
 UV-B has wavelengths from 290 -320nm
 UV-C has wavelengths from 100 – 290nm

Visible light is measured in photometric units

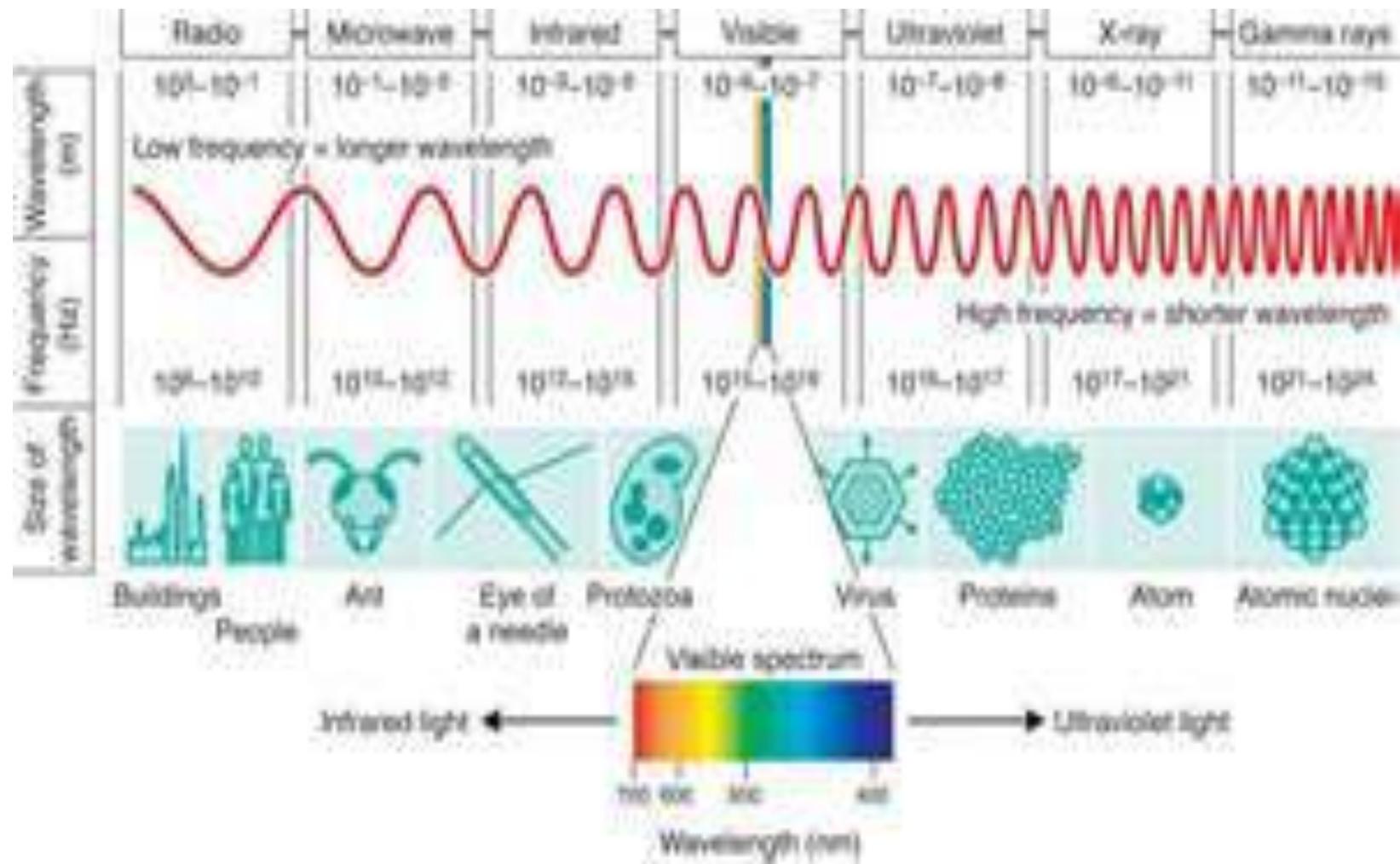
Illuminance the quantity of light striking a surface

Luminance the intensity of a light source.

UV and **IR** radiation can be measured in radiometric units

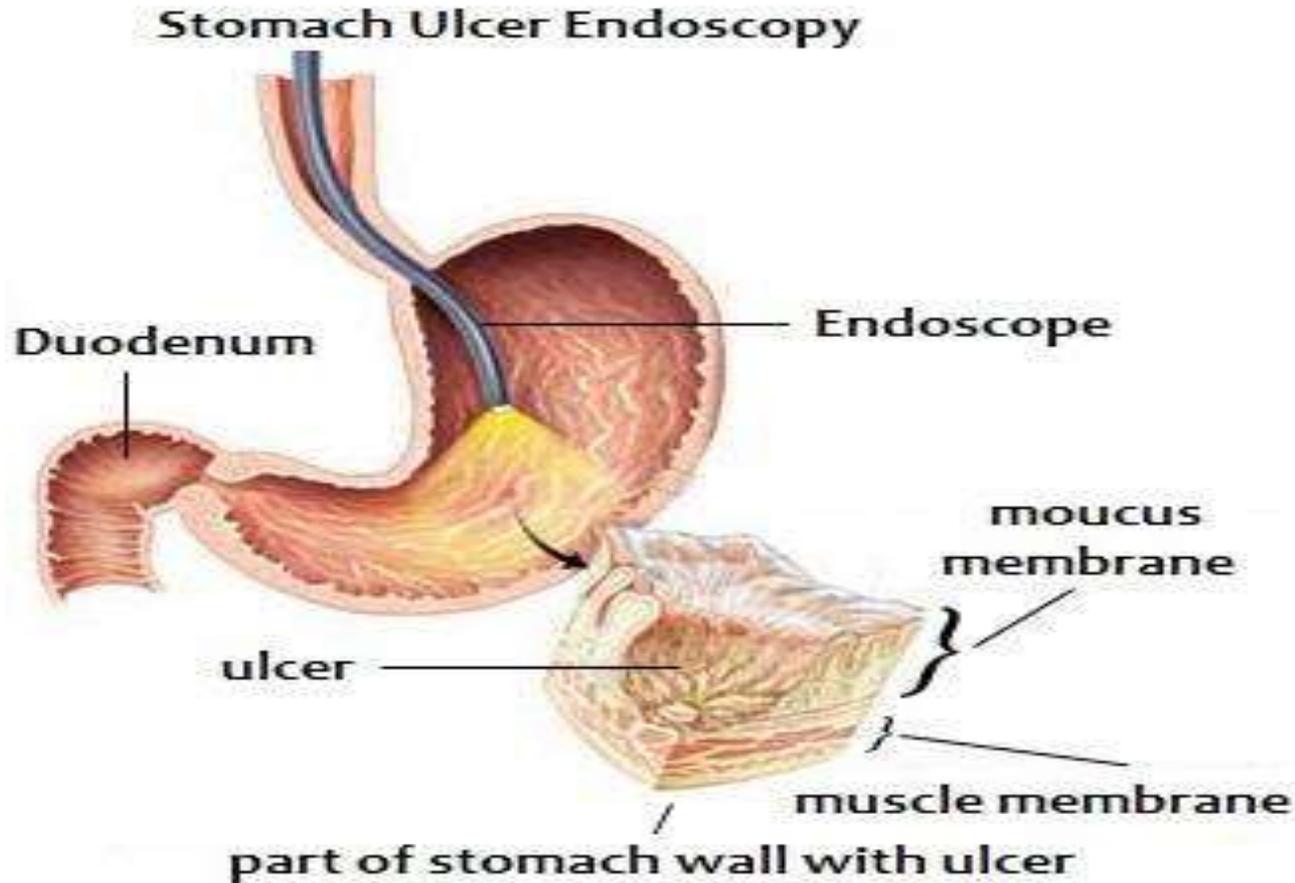
Irradiance the quantity of light striking a surface.

Radiance the intensity of a light source

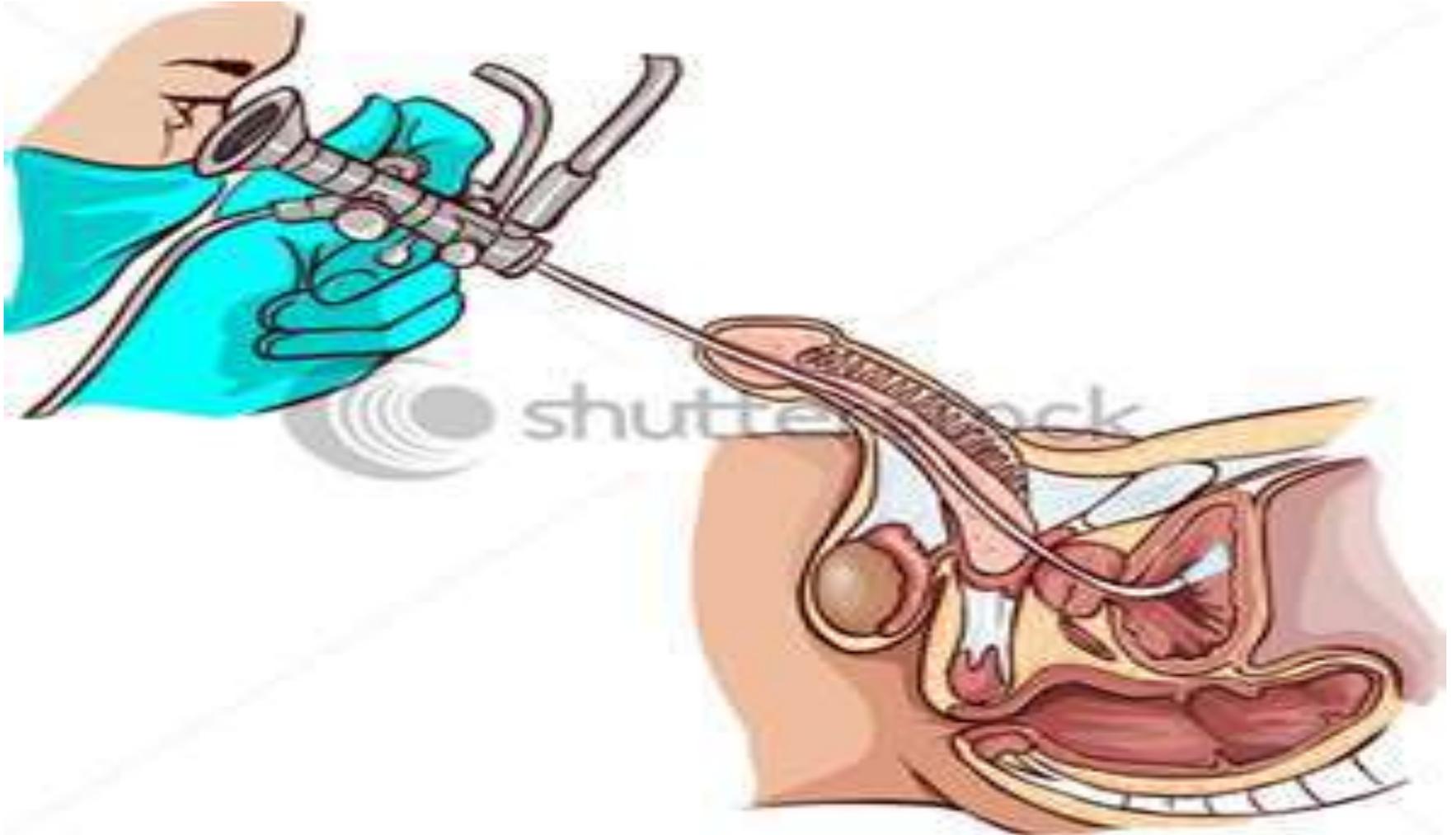


APPLICATIONS OF VISIBLE LIGHT IN MEDICINE

Endoscope: a number of instruments are used for viewing internal body cavities.

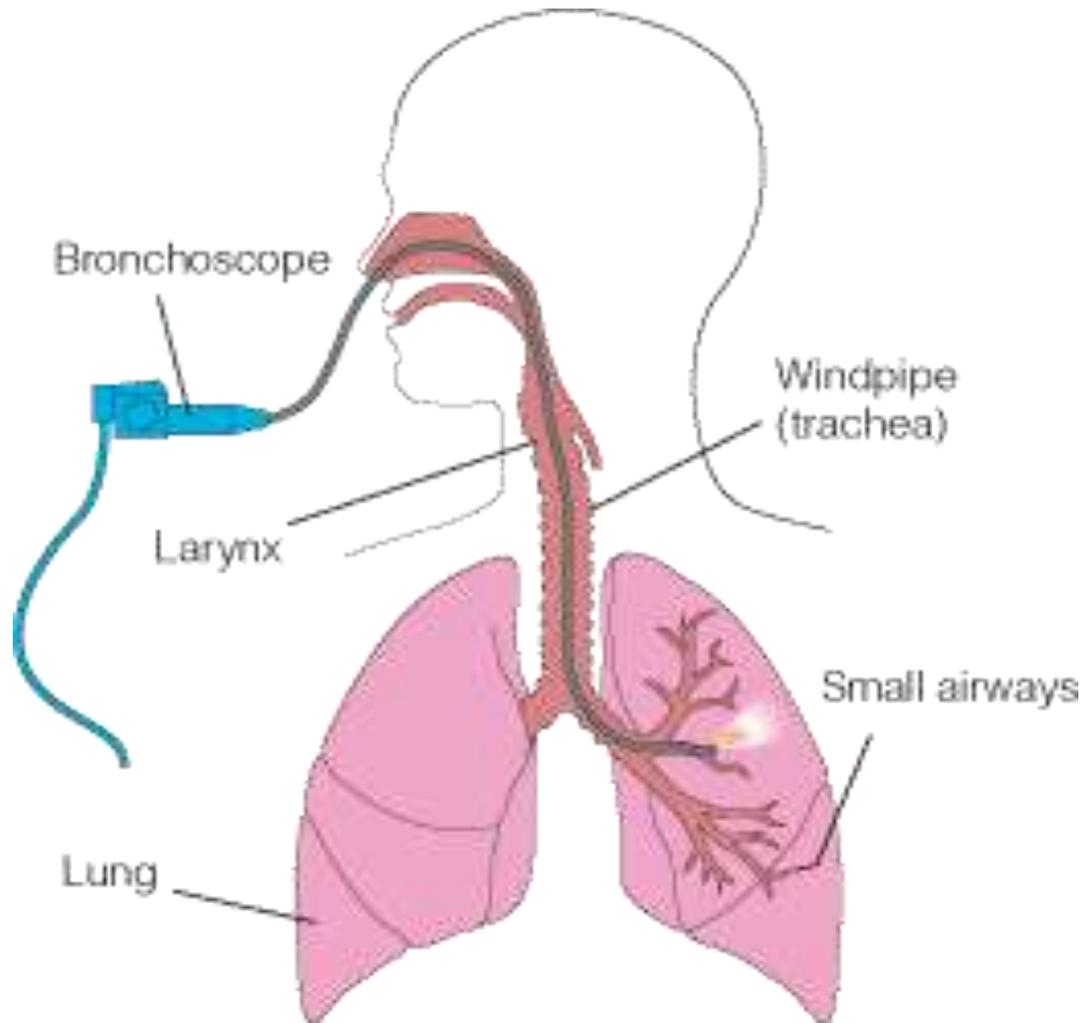


CYTOSCOPIES: are used to examine the bladder.



BRONCHOSCOPE: Are used for examining the air passages into lungs. Some endoscopes are rigid tubes with a light source to illuminate the area of interest.

Flexible endoscopes can be used to obtain information from regions of the body that cannot be examined with rigid endoscopes, such as the small intestine and much of large intestine.



APPLICATIONS OF UV AND IR LIGHT IN MEDICINE

UV photons have energies greater than visible and IR light. Because of their higher energies, UV photons are more useful than IR photons. •

-UV can kill germs and used to sterilize medical instruments. •

-UV produces more reaction in the skin some of these reactions are beneficial, and some are harmful. •

Beneficial effects of UV light from the sun is the conversion of molecular products in the skin into vitamin D.

Harmful effects of UV light can produce sunburn as well as tan skin. Solar UV light is also cause of skin cancer in humans. The high incidence of skin cancer among people who have been exposed to the sun a great deal, such as fishermen and agricultural workers, many be related to the fact that the UV wavelengths that produce sunburn are also very well absorbed by the DNA in the cells.

UV light has even shorter wavelengths than the visible light and is scattering more easily. About half of the UV light hitting the skin on a summer day comes directly from the sun and other half is scattered from the air in the other parts of the sky. Thus you can get a sunburn even when you are sitting in the shade under a small tree.

-UV light cannot be seen by the eye because it is absorbed before it reaches the retina.

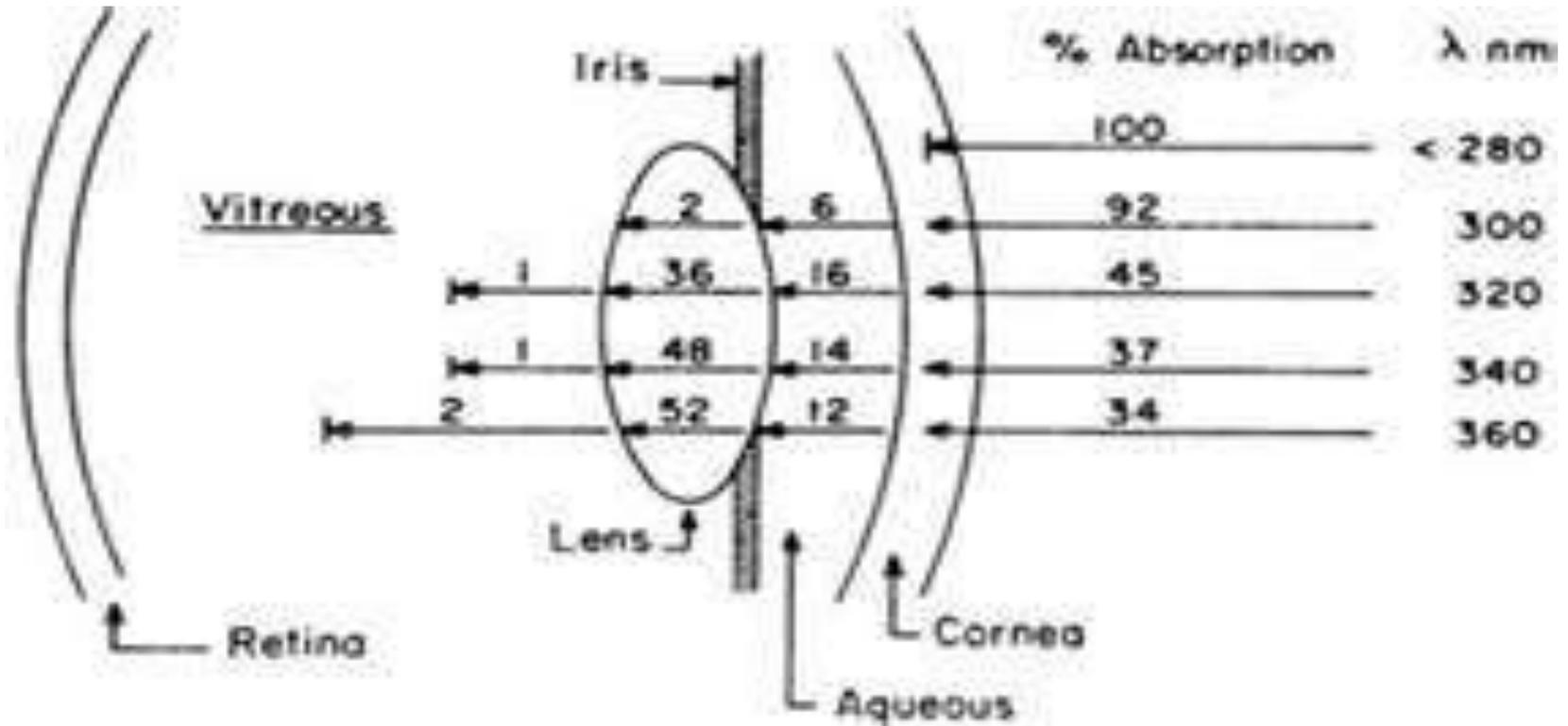


Fig shows the percentages of UV light of different wavelengths absorbed by the different structures of the eye

The IR rays are not usually hazardous even though they are focused by the cornea and lens of the eye onto the retina. However, looking at the sun through a filter (e.g., plastic sunglasses) that removes most of the visible light and allows most of the IR wavelengths through can cause a burn on the retina.

Heat lamps that produce a large percentage of IR light with wavelengths of 1000 to 2000nm are often used for physical therapy purposes.

Two types of IR photography are used in medicine:

1- Reflective IR photography

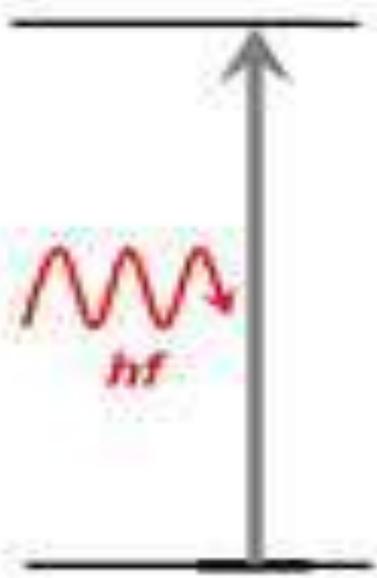
Which uses wavelength of 700 to 900nm to show patterns of veins just below the skin.

2- Emissive IR photography.

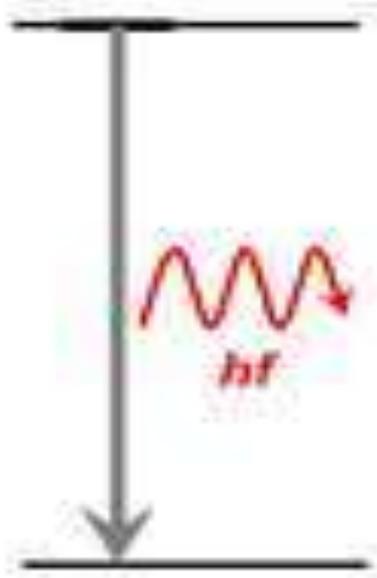
Which uses the long IR heat waves emitted by the body that give an indication of the body temperature, is usually called thermograph.

LASER IN MEDICINE

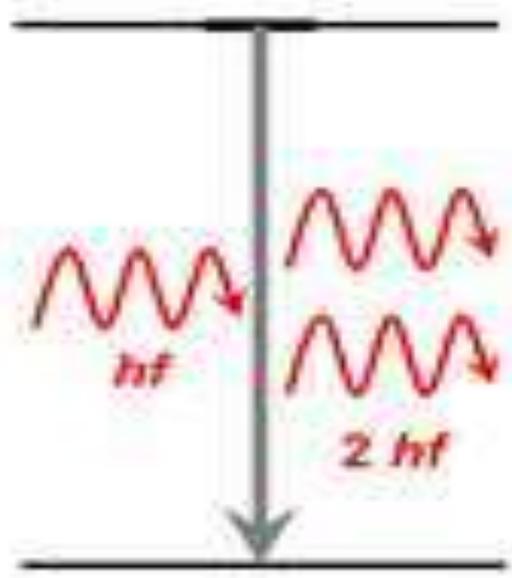
- When an electron makes a transition from higher energy to lower energy state, a photon is emitted. The emission process can be one of two types, spontaneous emission or stimulated emission.
- In spontaneous emission the photon is emitted spontaneously, in a random direction, without external provocation.
- In stimulated emission an incoming photon stimulates the electron to change energy levels. To produce stimulated emission, however, the incoming photon must have energy that exactly matches the difference between the energies of two levels, namely



absorption



spontaneous emission



induced emission

The operation of lasers depends on stimulated emission.

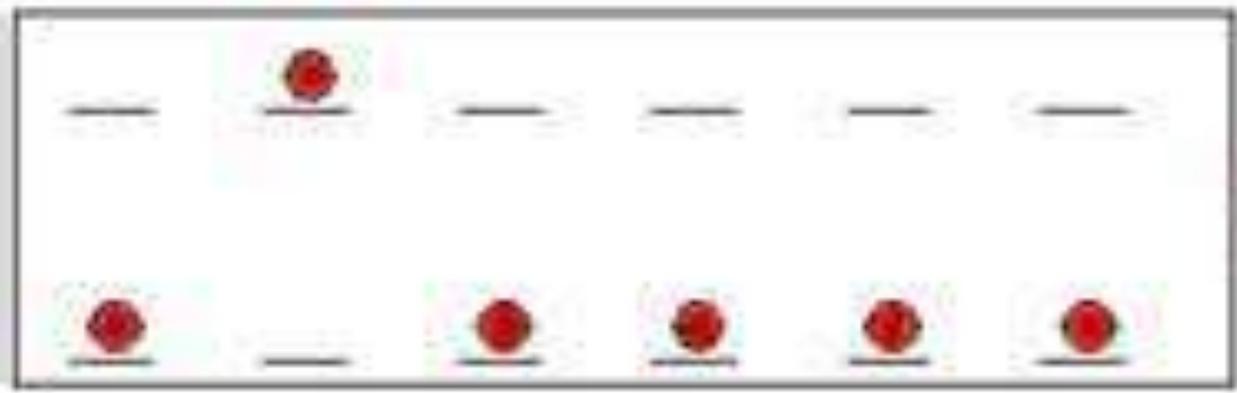
Stimulated emission has three important features.

1-One photon goes in and two photons come out. In this sense, the process amplifies the number of photons. This is the origin of the word laser which is an acronym for light amplification by the stimulated emission radiation

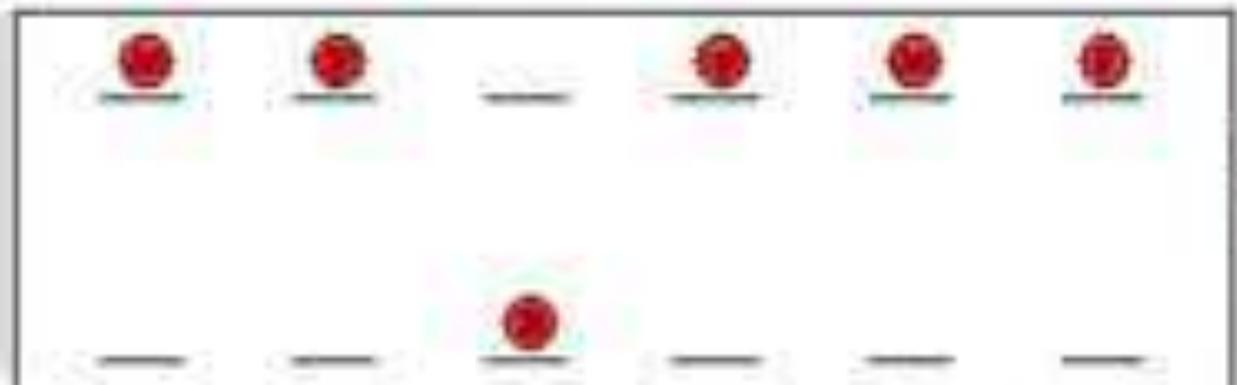
2-The emitted photon travels in the same direction as incoming photon.

3-The emitted photon is exactly in step with or has same phase as the incoming photon. In other words, the two electromagnetic waves that these two photons represent are coherent.

The energy can be provided in number of ways, including intense flashes of ordinary light and high voltage discharges. If efficient energy is delivered to atoms, more electrons will be excited to a higher energy level than remain in lower energy level, a condition known as population inversion. Figure compares a normal energy level population with a population inversion. The population inversion in lasers involve a higher energy state that is metastable, in the sense that electrons remain in it for a much long period of time than they do in an ordinary excited state (10^{-3} s versus 10^{-8} s)



normal
population



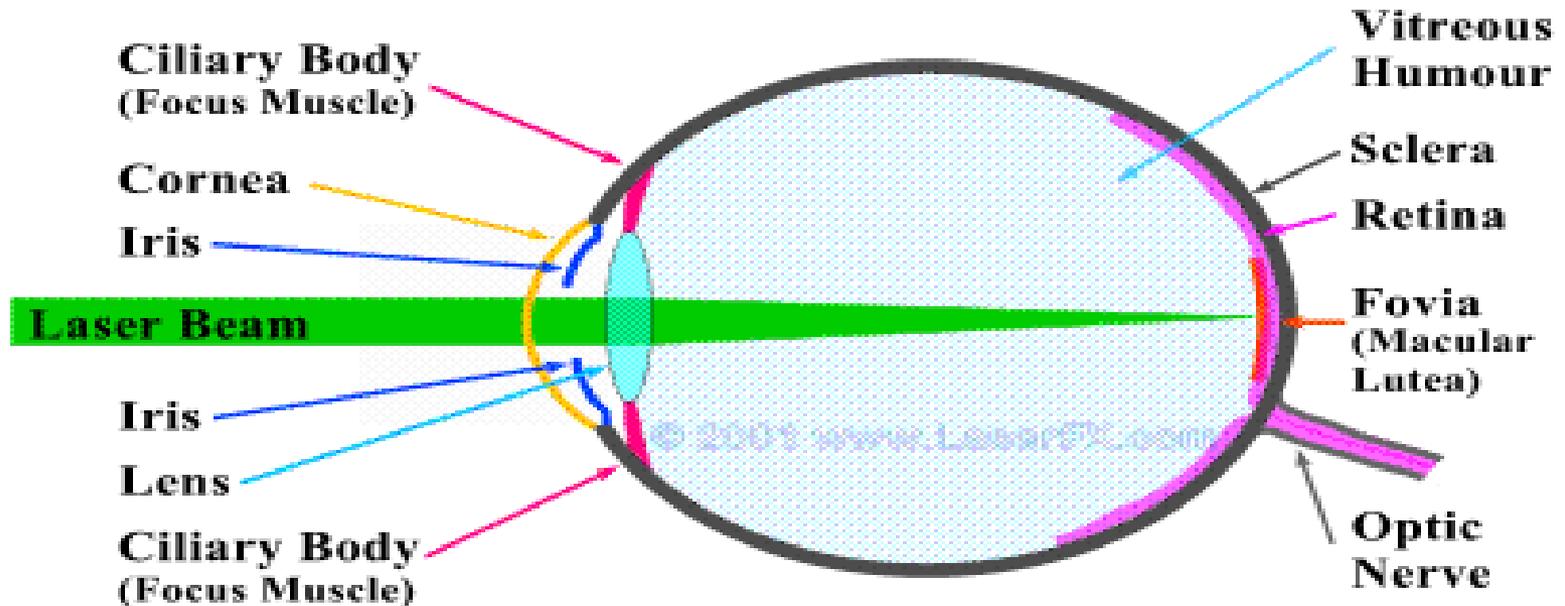
population
inversion

A laser is a unique light source that emits a narrow beam of light of single wavelength in which each wave is in phase with others near it. The physical characteristics of lasers and a few of their application in medicine.

Laser energy that has been stored in the laser material.

A laser beam can be focused to a spot only a few microns in diameter. When all of the energy laser concentrated in such a small area, the power density (power per unit area) becomes very large. The total energy of a typical laser pulse used in medicine, which measured in milli joules (mJ), can be delivered in less than a microsecond, and resultant instantaneous power may be in megawatts. The output of pulsed laser is usually measured by the heat produced.

Simplified Cross Section of the Human Eye

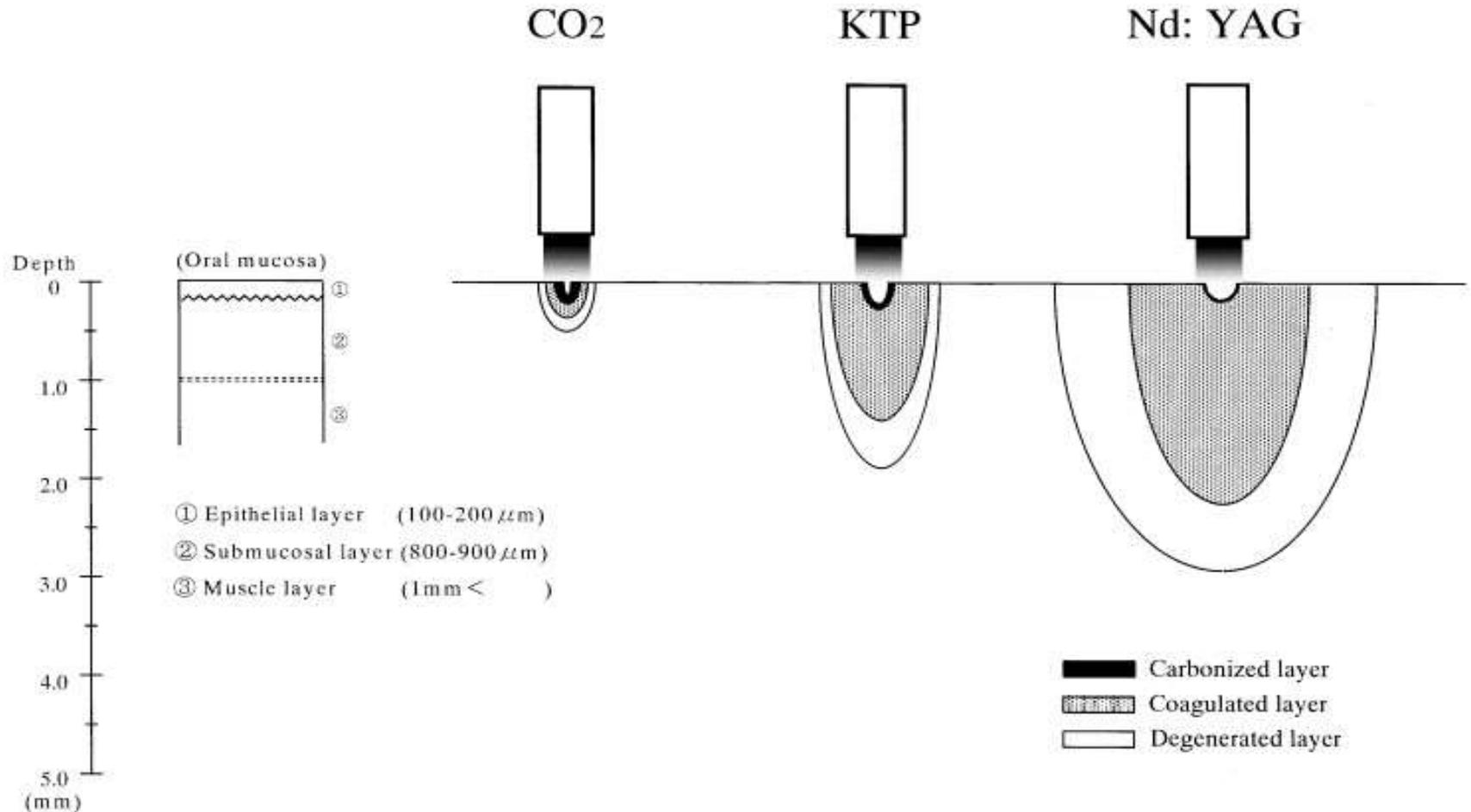


Laser beams are almost parallel thus the eye's lens will focus them down to a small spot causing retinal burns.

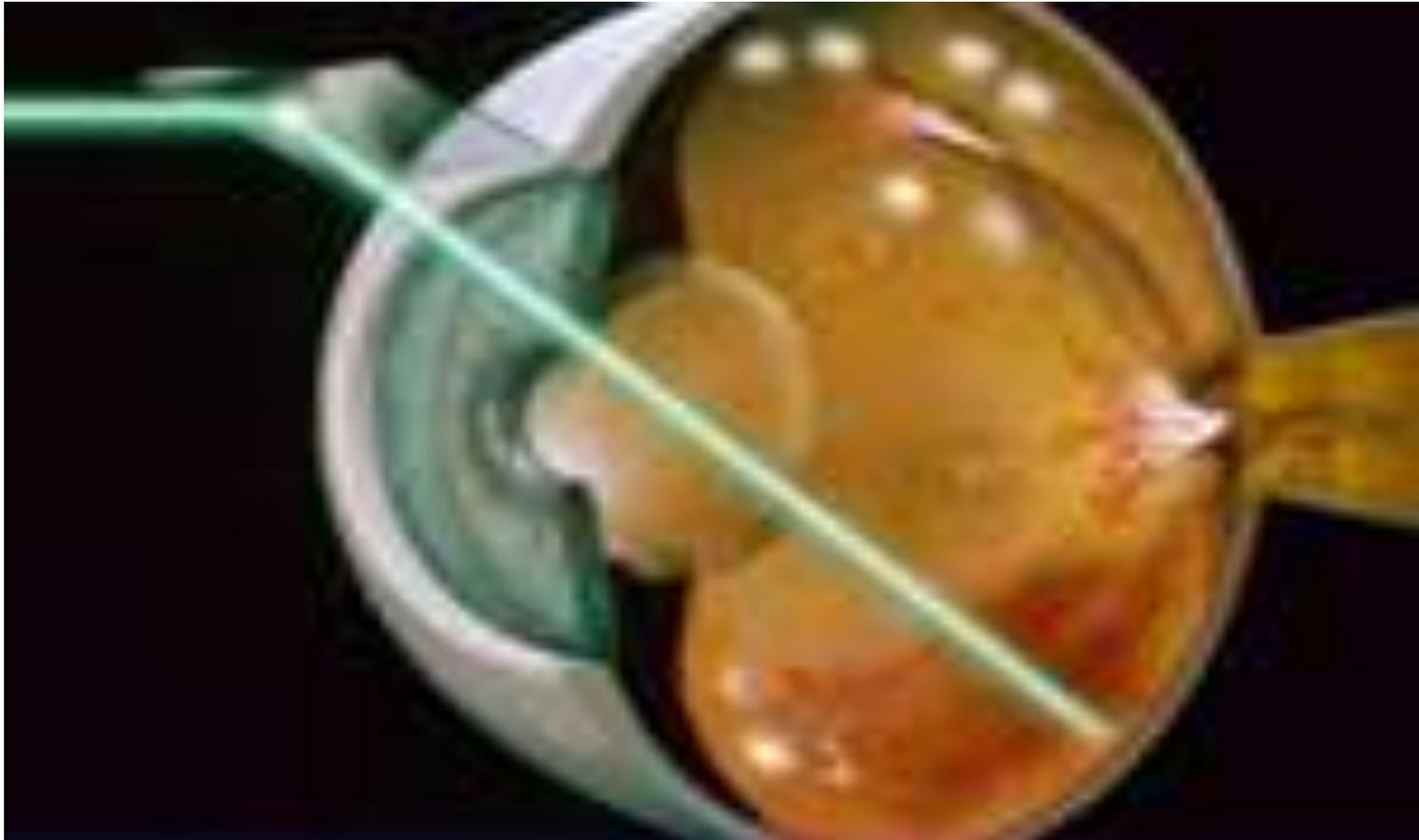
Since in medicine lasers are used primarily to deliver energy to tissue, laser energy directed at human tissue causes a rapid rise in temperature and can destroy the tissue. The amount of damage to living tissue depends on how long the tissue is at the increased temperature.

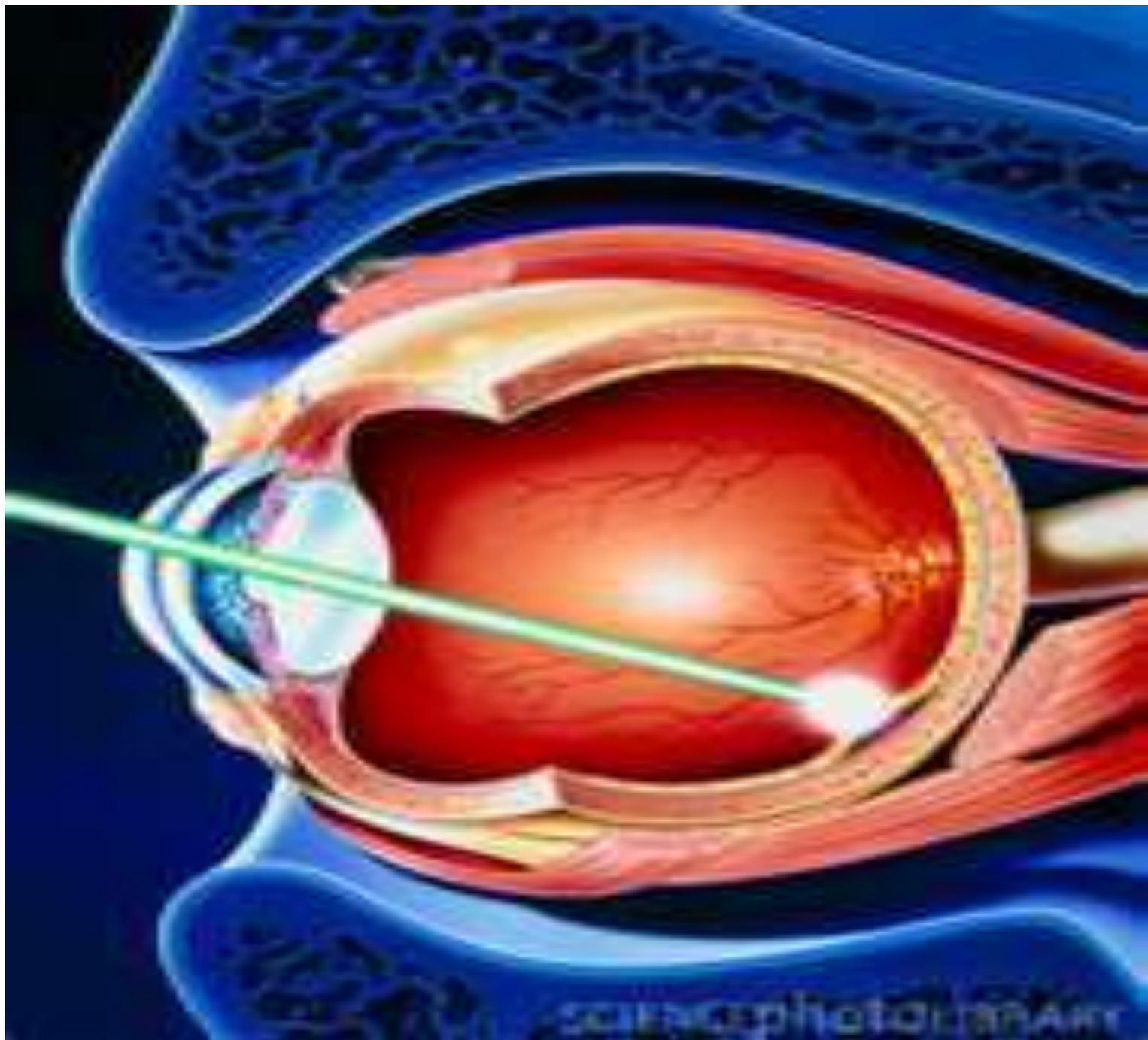
--For example, tissue can withstand 70C° for 1 s, in general even the briefest exposure to temperatures above 100Co results in tissue destruction. However, not all laser damage is due to heat.

The laser used in medicine as a blood less knife for surgery. It can be focused by a lens to almost a mathematical point. This means that the energy per unit area in the focal spot can be made enormous, and small regions can be vaporized without harming the surroundings.



In medicine one of the most spectacularly successful uses of lasers has been in ophthalmic surgery. In eye the retina may become detached from the choroid owing to disease, injury, or degenerative changes. The laser are primarily used for photocoagulation of the retina, the heating a blood vessel to point where the blood coagulates and blocks the vessel.





....it has been found that a 1ms flash of light from a laser focused on the retina is highly efficient in welding the retina to choroid. Further, the patient feels no pain and no anesthetic is not required. The amount of laser energy needed for photocoagulation depends on the spot size used. In general, the proper dose is determined visually by the ophthalmologist at the time of the treatment.

The minimum amount of laser energy that will do observable damage to the retina is called minimal reactive dose(MRD).

Example:

The MRD for a $50\mu\text{m}$ spot in the eye is about 2.4mJ delivered in 0.25 s.

Typical exposure needed for photocoagulation are 10 to 50 times the MRD (i.e., 24 to 120mJ for $50\mu\text{m}$ spot in 0.25s)

Photocoagulation is useful for repairing retinal tears or holes that develop prior to retinal detachment. When the retina is completely detached, the laser is of no help. A complication of diabetes that affects the retina called diabetic retinopathy, can also be treated with photocoagulation. Because of the small spot sizes available ($\sim 50\mu m$) it is possible to use the laser even in the small region where our detail vision takes place.

Protective glasses must be worn in medical laser areas to protect the eyes of the patient and the workers. Since the laser energy is concentrated in a narrow beam for long distances, even reflected beam can be a hazard: thus the walls and other surfaces in the laser installation should have low reflectivity (e.g. flat black paint). The area should have adequate warning and system that prevents outsider from entering while lasers are in use.